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Trace Metals in Scallops from Within and Around Two Ocean Disposal Sites

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Trace Metals in Scallops from Within and Around Two Ocean Disposal Sites

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The areal distributions of the concentrations of 13 metals in sea scallop tissues were examined in the vicinity of two ocean disposal sites located off the U.S. mid-Atlantic coast. Patterns of metals distribution show that: (1) Five specific metals may be used as identification tags for individual wastes diposed at the two sites, and (2) disposed materials tend to be transported by currents south and southwest from the disposal sites, and (3) biological availability and potential toxicity of metals pose a threat to marine biota.

The oceans are viewed by many as a vast sink for disposal of waste materials. It is assumed that dilution and assimilation of harmful wastes are safely accomplished in the oceans. This assumption needs to be examined.

Tons of nondegradable contaminants, such as metals, are disposed annually in the ocean. Little quantitative information is available on fate and effect of these contaminant loadings, so it is difficult to estimate levels of threat posed to marine biota in the vicinity of disposal sites. To gain some information on fate and biological availability of waste constituents, metal concentrations were measured in tissues of the sea scallop, *Placopecten magellanicus,* collected from the vicinity of two disposal sites off the mid-Atlantic coast of the United States. This area was selected for study because of its relative isolation from other anthropogenic sources of pollutants.

The objective of this research programme was to determine if benthic organisms, frequently exposed to waste material, would reflect elevated concentrations in their tissues of metals contained in those wastes. It was postulated that distribution pattern of metal concentration would correspond to expected current transport from the disposal sites.

Since November 1968, E.I. DuPont de Nemours Company has been ocean disposing acid wastes from a titanium dioxide plant located at Edge Moor, Delaware. The dump site is located 65 km southeast of Delaware Bay. The city of Philadelphia has used a second site, located 9 km southeast of the first, to dispose of sewage sludge from secondary treatment since May 1973 (Fig. 1). The amounts and chemical constituents of both wastes may be estimated from information supplied as a requirement of dumping permits (Table 1). From an examination of the relative differences in chemical composition of the two wastes it seemed that metals may provide useful tags for tracing the fate of these materials. The sewage sludge, for example, accounts for most of the copper, silver, lead, nickel, and cadmium disposed in the area; the acid waste accounts for most of the titanium, vanadium, manganese, and iron.

The disposal sites are located on a level portion of the continental shelf with sediments of medium to fine sand and water depths of 45–55 m. In general, surface currents

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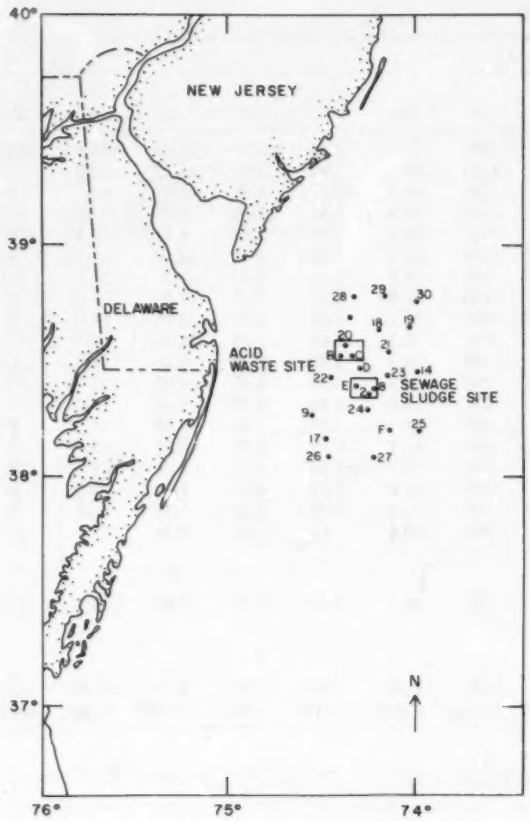

Fig. 1 Station locations for cruise, March 1974.

flow south from these sites with an onshore component during the warm half of the year and an offshore component during the cold half. Bottom currents flow south with an onshore component persistant year round (Bumpus *et al.*, 1973). Both wastes are dumped at controlled rates into the wake of moving barges traversing the dumpsites.

Materials and Methods

In March 1974, samples of sea scallops, *Placopecten magellanicus*, were collected from a 4100 km² area in and around these disposal sites. Half hour tows with a 12 toothed Fall River rocking chair dredge yielded from 2 to more than 10 individuals at 19 out of a total of 24 stations sampled (Table 2). Where a large number of individuals were obtained, the sample size was limited to 10, while stations yielding less than 2 individuals were eliminated from further consideration. Immediately upon collection, the scallops were counted, placed into labeled plastic bags, and frozen on dry ice. All samples were maintained frozen until prepared for analysis.

In the laboratory, the scallops were individually weighed, measured, shucked into clean, acid-washed, and tared Pyrex beakers, and then reweighed. Dry weights were determined after drying at 80–90°C for 48 h. The samples were then wet digested at 85–95°C in concentrated HNO_3 until the resulting solution became clear pale yellow with no apparent nitric oxide fumes or lipids remaining. After bringing to near dryness, the samples were diluted in 5% HNO_3, filtered through No. 42 acid washed Whatman paper, and further diluted to a final volume of 50 ml with additional 5% HNO_3. All samples were analysed individually for 13 metals contained in the two wastes, using a Perkin–Elmer Model 403 atomic absorption spectrophotometer, following recommended standard operating parameters and procedures. Each sample was analysed in triplicate and the results averaged. Matrix interferences were corrected in the vanadium analysis by adding aluminium salts to the calibration standards. These corrections were routinely verified by the recovery of spikes of standard solutions added to selected samples.

TABLE 1
Volumes and composition of wastes disposed at Philadelphia and DuPont ocean dumpsites.

Total input	DuPont*	Philadelphia§
gal/yr	118 000 000	130 400 000
l/yr	446 700 000	493 400 000
spec. gr.	1.19	1.029
kg/yr	531 600 000	507 800 000

Individual metal input (kg)

	DuPont*				Philadelphia§			
	Annual (1974)	%	Total Nov 68–Dec 74	%	Annual (1974)	%	Total May 73–Dec 74	%
Fe	21 400 000	98.3	132 000 000	99.6	364 000	1.7	592 000	0.4
Cu	2 400	6.9	14 800	21.9	32 600	93.1	52 900	78.1
Cr	39 600	51.7	244 000	81.7	37 000	48.3	54 800	18.3
Al	364 000	25.0	2 240 000	55.7	1 090 000•	75.0	1 790 000•	44.3
Ag	270	10.4	1 670	31.1	2 300•	89.6	3 700	68.9
Mn	572 000	94.4	3 530 000	98.5	33 700	5.6	54 800	1.5
Pb	5 630	7.0	34 700	2.8	74 800	93.0	1 220 000	97.2
Co	4 800	35.5	29 600	67.7	8 700•	64.5	14 100•	32.2
Ni	4750	12.3	29 300	34.8	33 800	87.7	54 900	65.2
V	74 300	99.8	458 000	95.95	150	0.2	227	0.05
Cd	338	10.8	2 080	31.4	2 800	89.2	4 500	68.6
Zn	18 300	22.7	113 000	52.8	62 300	77.3	101 000	47.1
Ti	733 000	99.2	4 520 000	99.8	5 900	0.8	9 600	0.2

*Estimates based on DuPont reports submitted to EPA for period 6 Feb–11 July 1974. §Estimates based on Philadelphia reports submitted to EPA for period 14 Feb–6 Aug 1974 except where noted. •Estimates based on ERL analysis of submitted samples of waste.

TABLE 2
Mean metal concentrations (ppm/dry wt) *Placeopecten magellanicus* whole animal tissue collected from within and around two ocean disposal sites.

Station	Sample size	Ag	Al	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Ti	V	Zn
E	10	0.58	201	11.1	0.48	3.31	6.31	400	28.8	2.64	2.80	6.03	34.4	108
F	10	0.81	904	24.9	1.02	4.56	6.81	2220	63.2	2.99	3.96	26.22	20.8	101
2	5	9.08	92	10.9	0.52	2.65	12.65	190	16.1	14.67	1.96	5.02	40.7	118
8	9	4.16	197	13.1	0.38	2.71	9.69	1040	29.4	7.84	7.09	6.76	37.2	124
9	3	0.45	92	15.6	0.29	2.64	7.54	261	24.3	2.08	2.52	4.53	39.4	116
14	8	0.48	617	59.3	0.65	2.73	6.69	1480	32.8	1.89	3.99	12.00	21.2	96
17	9	2.15	775	15.1	0.37	4.19	8.81	701	38.8	6.00	3.99	10.97	37.9	122
18	8	0.71	506	11.4	0.65	2.76	5.16	1410	41.8	1.91	2.45	17.27	21.6	96
19	3	0.39	152	37.5	0.48	2.85	4.27	565	32.2	1.06	1.84	4.98	14.0	93
20	2	1.11	313	10.8	0.78	2.01	5.63	682	22.7	1.65	1.64	16.30	19.5	101
21	4	0.64	203	14.2	0.43	2.90	5.25	1180	29.3	2.06	2.06	8.68	24.4	82
22	10	2.96	166	14.7	0.45	4.05	8.63	250	26.9	6.33	1.83	6.82	31.7	127
23	6	1.24	139	19.5	0.66	2.08	8.29	251	12.0	4.34	1.20	9.26	24.0	103
24	10	0.43	155	22.6	0.58	1.17	6.14	339	18.5	1.97	1.54	5.48	31.3	94
25	2	1.13	127	26.0	0.76	0.89	6.73	243	12.9	4.19	3.73	6.21	18.0	99
26	5	4.93	78	10.8	0.69	6.88	9.50	286	13.0	13.65	5.78	1.06	45.7	94
27	4	0.43	342	55.9	0.54	3.26	6.28	1110	22.8	1.35	6.91	9.19	16.6	89
28	3	0.46	145	10.1	0.33	1.27	4.79	576	17.1	1.09	1.22	7.35	11.4	76
30	3	0.50	229	19.6	0.38	0.94	4.01	508	30.4	1.03	1.69	8.46	13.7	107
	114													
Overall means		1.80	338	20.9	0.56	3.08	7.31	803	29.8	4.41	3.59	9.80	28.5	105
ANOVA														
f value		3.20	2.02	6.80	1.12	3.22	5.08	2.00	2.34	5.51	1.52	2.79	15.80	1.25
P value		0.0002	0.0151	0.0001	0.3499	0.0002	0.0001	0.0166	0.0046	0.0001	0.0982	0.0009	0.0001	0.2389

Results

Mean metal concentrations for scallops and the numbers analysed for each station are listed in Table 2. The data for each metal were subjected to one way (by station) analysis of variance (ANOVA) to test for any significant concentration differences among the stations at the 95% confidence limit ($p = 0.05$) (Table 2). Further testing, using Duncan's Multiple Range Test, identified those specific stations having significantly high concentrations (Barr & Goodnight, 1972). To facilitate interpreting these data, they are presented in Figs 2–6 depicting mean concentrations for five metals at each station.

Three of the five metals identified as tags for the Philadelphia sewage sludge (silver, copper, and nickel) have their highest concentrations within the geographical confines of the Philadelphia dumpsite. Elevated concentrations are found at stations located down current, southwest from the dumpsite (Figs 2–4). A fourth metal, cadmium, shows highest concentrations northeast and south of the site in a pattern having a similar orientation to the first three metals but displaced seaward of the dumpsite (Fig. 5). Vanadium, a tag for the acid waste, shows a zone of significantly high concentrations south of the DuPont disposal site (Fig. 6).

Discussion

Elevated metal concentrations have been detected at many marine sites exposed to acid wastes or sewage sludge. Acid wastes from a titanium dioxide factory near Bremerhaven have been disposed in the German Bight since May 1969, (Weichart, 1972). Five and a half months after beginning disposal, elevated iron concentrations in seawater samples were found in an area of about 515 km². Since autumn 1969, ferric hydroxide floc has been found on the bottom. In areas well removed from this dumpsite in the direction of expected transport, there were indications of iron uptake in the soft tissues of the filter-feeding bivalve, *Venus gallina* L. (Rachor, 1972). Since 1948, a similar acid waste from titanium dioxide production by N.L. Industries has been disposed in New York Bight. In 1970, a study by Vaccaro *et al.* (1972) described findings of a brown, flocculent,

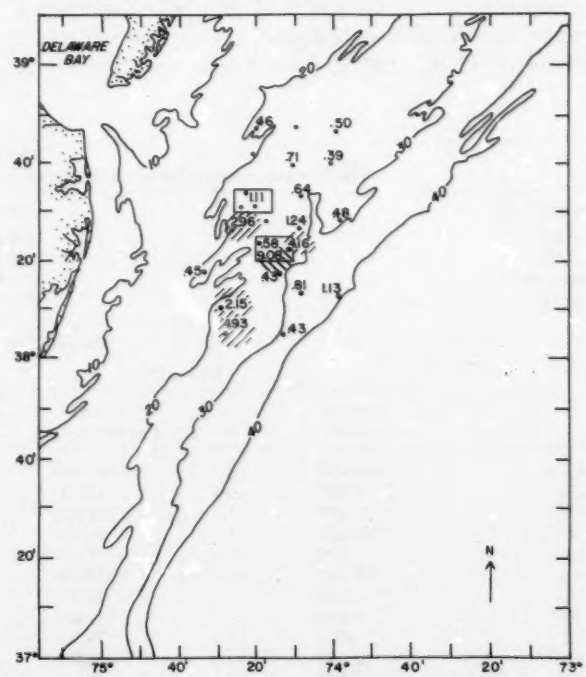

Fig. 2 Mean silver concentrations for dry weight of sea scallop tissues. Stations with statistically significant high concentrations are cross hatched to right. Stations with mean concentrations greater than the overall mean are cross hatched to left. Depth contours in fathoms.

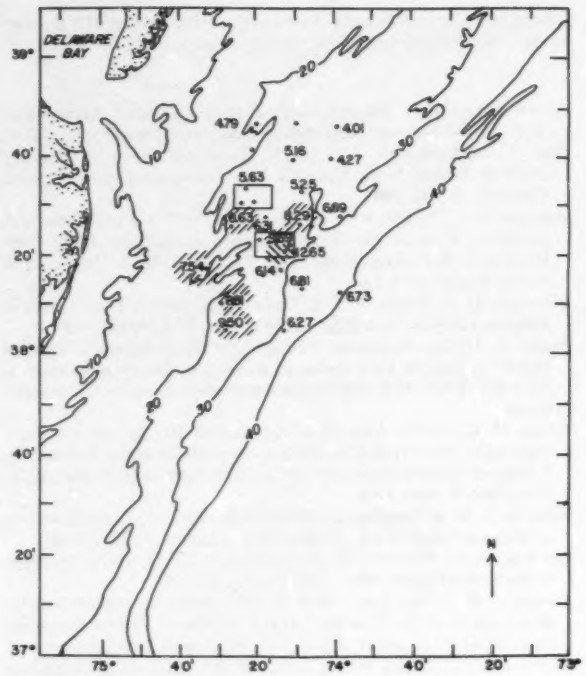

Fig. 3 Mean copper concentrations for dry weight of sea scallop tissue. Stations with statistically significant high concentrations are cross hatched to right. Stations with mean concentrations greater than the overall mean are cross hatched to left.

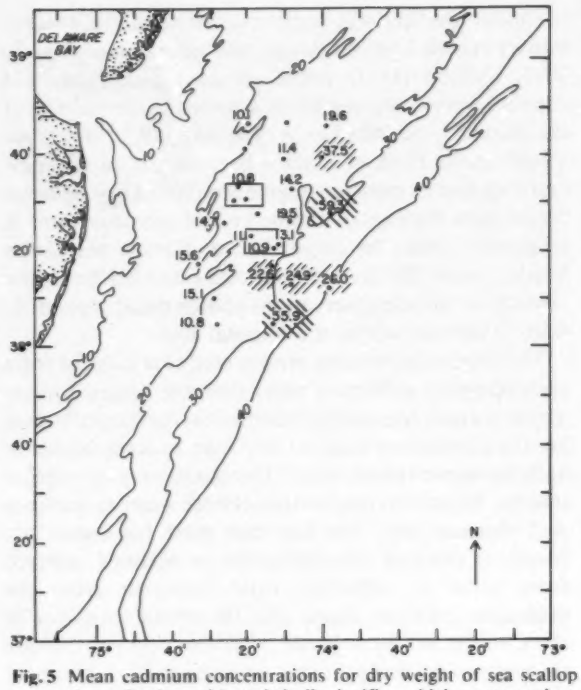

Fig. 5 Mean cadmium concentrations for dry weight of sea scallop tissue. Stations with statistically significant high concentrations are cross hatched to right. Stations with mean concentrations greater than the overall mean are cross hatched to left.

particulate material, probably ferric hydroxide floc, on the bottom of the acid waste disposal site. Elevated metal concentrations in zooplankton, benthos, and sediments were also detected.

Large quantities of other waste materials from the New York Metropolitan area have been disposed in the New York Bight for nearly a century. Carmody *et al.* (1973), studying the distribution of metals in sediments in and around the dredge spoil and sewage sludge sites, found two central regions of high concentration and zones of elevated metal concentrations extending 30 km southeast and 12 km northeast of the disposal sites. Distribution of coliform bacteria and organic matter correlated well with that of the metals. Areas affected by sewage sludge were found to be "devoid of normal benthic populations" (Pearce, 1972).

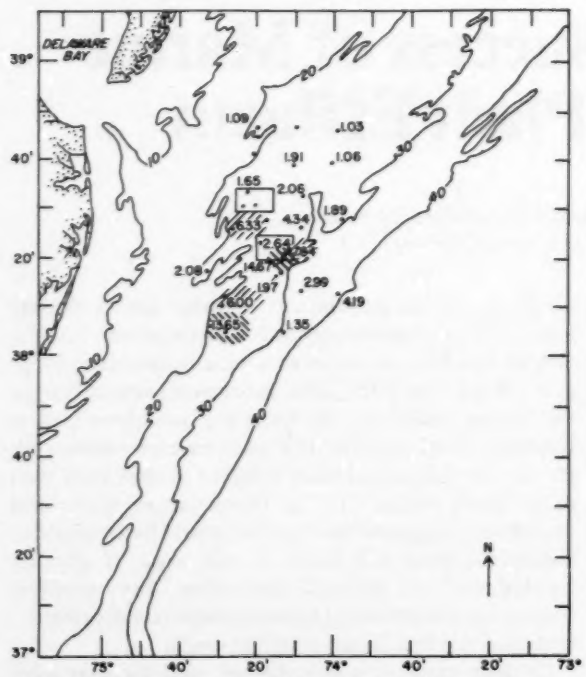

Fig. 4 Mean nickel concentrations for dry weight of sea scallop tissue. Stations with statistically significant high concentrations are cross hatched to right. Stations with mean concentrations greater than the overall mean are cross hatched to left.

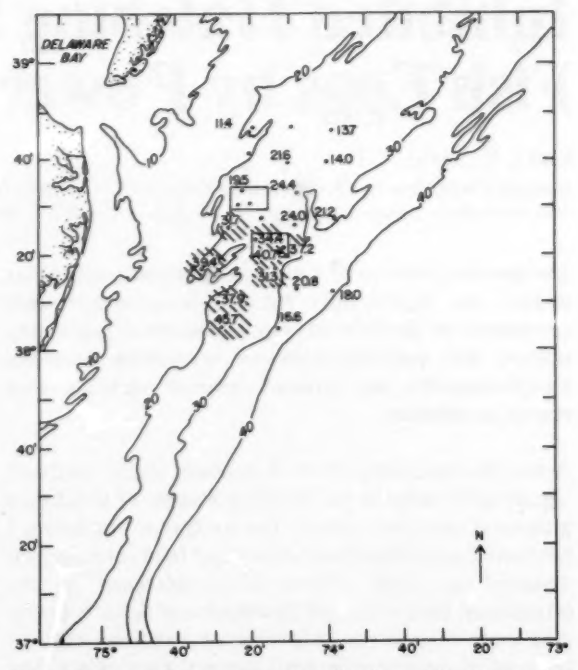

Fig. 6 Mean vanadium concentrations for dry weight of sea scallop tissue. Stations with statistically significant high concentrations are hatched to right.

Similar studies have been conducted in the Thames estuary where London sludge has been disposed since 1887. Shelton (1971) found elevated zinc, lead, and copper levels in organic muds sampled in the vicinity of the disposal site. Mackay & Topping (1970) described studies in the Firth of Clyde where the city of Glasgow had disposed its sewage sludge since 1904. They reported preliminary findings of elevated metal concentrations in sediments within the disposal area. Further studies by Mackay *et al.* (1972) confirmed and extended the earlier findings to include observations of high metal concentrations in animals within the disposal area.

The disposal sites in the present study are isolated from anthropogenic influences other than the barged wastes, hence, we may reasonably assume that the barged wastes are the dominant source of any high concentrations of anthropogenic metals which therefore, may be used as tracers. The metal composition of both waste materials is well characterized. The fact that these tag metals are found in elevated concentrations in scallops sampled from areas of expected waste transport from the dumpsites indicates clearly that the metals contained in these wastes are biologically available, not only within the limits of the dumpsites but, in many cases, far beyond. In the case of the metals attributable to the sewage sludge, the patterns of elevated concentration have occurred within a period of 10 months after the initiation of dumping. Because of their biological availability and toxic properties (Eisler, 1973; Anon, 1972) these metals pose a threat to marine biota.

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Anonymous (1972). *Water Quality Criteria.* National Academy of Sciences and National Acacemy of Engineering, Washington, D.C.

Barr, A. J. & Goodnight, J. H. (1972). *A User's Guide to the Statistical Analysis System.* North Carolina State University, Raleigh, North Carolina. pp. 138–164.

Bumpus, D. F., Lynde, R. E. & Shaw, D. M. (1973). Physical oceanography in: Coastal and Offshore Environmental Inventory; Cape Hatteras to Nantucket Shoals. Mar. Pub. Sers. No. 2. University of Rhode Island, pp. 1–72.

Carmody, D. J., Pierce, J. B. & Yasso, W. E. (1973). Trace metals in sediments of New York Bight. *Mar. Pollut. Bull.*, 4, 132–135.

Eisler, R. (1973). Annotated Bibliography on Biological Effects of Metals in Aquatic Environments. Ecological Research Series. No. EPA-R3-73-007. U.S. Environmental Protection Agency, Corvallis, Oregon.

Gross, M. C. (1970) Analysis of dredged wastes, fly ash and waste chemicals—New York Metropolitan Region. Technical Report No. 7. Marine Sciences Research Center, State University of New York, Stony Brook, New York.

Mackay, D. W. & Topping, G. (1970). Preliminary report on the effects of sludge disposal at sea. *Effluent Wat. Treatmt. J.*, 10, 641–649.

Mackay, D. W., Halcrow, W. & Thornton, I. (1972). Sludge dumping in the Firth of Clyde. *Mar. Pollut. Bull.*, 3, 7–10.

Pearce, J. B. (1972). The effects of solid waste disposal on benthic communities in the New York Bight. In *Marine Pollution and Sea Life.* pp. 404–411, ed. M. Ruivo, Fishing News (Books) London.

Rachor, E. (1972). On the influence of industrial waste containing H_2SO_4 and $FeSO_4$ on the bottom fauna off Helgoland (German Bight). In *Marine Pollution and Sea Life.* pp. 390–392, ed. M. Ruivo, Fishing News (Books) London.

Shelton, R. G. (1971). Sludge dumping in the Thames Estuary. *Mar. Pollut. Bull.*, 2, 24–27.

Vaccaro, R. F., Grice, G. D., Rowe, G. J. & Wiebe, P. H. (1972). Acid-iron waste disposal and the summer distribution of standing crops in the New York Bight. *Wat. Res.*, 6, 231–256.

Weichart, G. (1972). Chemical and physical investigations on marine pollution by wastes of a titanium dioxide factory. In *Marine Pollution and Sea Life.* pp. 186–188, ed. M. Ruivo, Fishing News (Books) London.